Thermal Conductivity of SiGe/Si and SiGeC/Si Superlattices and their Application to Thermoelectric/Thermionic Cooling *

X. Fan,[1] G. Zeng, [1], C. Luo,[1] E. Croke,[2]
D. Clarke,[3] A. Shakouri,[4] and J.E. Bowers[1]

[1]*Department of Electrical and Computer Engineering*
University of California
Santa Barbara, CA 93106 U.S.A.

[2] *HRL Laboratories*
LLC, Malibu, CA 90265 U.S.A.

[3] *Department of Materials*
University of California
Santa Barbara, CA 93106 U.S.A.

[4] *Baskin School of Engineering*
University of California
Santa Cruz, CA 95064 U.S.A.

SiGe and more recently SiGeC are widely used in high-speed integrated circuits. In this paper, the 3ω method was used to evaluate the thermal conductivity of symmetrically strained SiGe/Si and SiGeC/Si superlattices grown with molecular beam epitaxy on Si substrates. The measured values for thermal conductivity of SiGe/Si superlattice are about 3 - 5 W/(mK). Similar results were obtained with SiGeC/Si superlattice. These materials were used to fabricate thermoelectric/thermionic micro-coolers. The fabrication and characterization of single-element SiGe/Si and SiGeC/Si superlattice coolers of both n and p type devices are described. Superlattice structures were used to enhance the device performance by reducing the thermal conductivity between the hot and the cold junctions, and by providing selective emission of hot carriers through thermionic emission. The device structure consisted of a 3 μm thick symmetrically strained $Si_{0.7}Ge_{0.3}$/Si superlattice grown on a buffer layer designed so that the in-plane lattice constant is approximately that of relaxed $Si_{0.9}Ge_{0.1}$. Cooling by 1.7 K for n type device and by 1.9 K for p type device at room temperature was measured. Si/Si cooler devices were fabricated for comparison with superlattice devices, the cooling of which are 0.8 K for p devices and 0.5 K for n devices. These show that superlattice lower thermal conductivity plays very important role in the device performance.

*This project is supported by DAPAR HERETIC program and the Army Research Office.